The underlying PCT application PCT/DE98/03741 includes an International Search Report, dated May 27, 1999. An English translation of the Search Report is provided herewith.

The underlying PCT application also includes an International Preliminary Examination Report ("IPER"), dated August 22, 2000. An English translation of the IPER and the annex thereto is included herewith.

It is respectfully submitted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully submitted,

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SWITCHING CONTROLLER

[Background of the Invention] FIELD OF THE INVENTION

The present invention relates to a switching controller in whose control loop an error signal amplifier is provided, which [essentially] exhibits P (proportional) action and which acts on a pulse duration modulator or frequency modulator for the final controlling element of the switching controller. [This type of switching controller is known from European Patent 0 355 333 B1.]

BACKGROUND INFORMATION

A controller of the above-mentioned type is described in European Patent No. 0 355 333.

PCT Application WO 97/34363 describes a switching controller which, besides the conventional control loop for the error signal at the output of the switching controller, has an additional control loop with which a correction quantity, which is a function of the load variation, is computed. This correction quantity is additively superimposed on the error signal in order to reduce voltage fluctuations given pulse-shaped load variations at the output of the switching controller.

U.S. Patent No. 4,885,674 describes a similar switching controller having two such control loops.

In the switching controller described in European Patent No. 0 355 333 [B1], noise signals on the input voltage are optimally suppressed in their effect on the output voltage of the switching controller without the control rate being adversely affected, for instance given sudden load variations. In order to prevent large voltage dips given sudden load variations at the output, for instance in the

TDMA operation of a traveling-wave amplifier in a satellite, the voltage control loop must be properly dimensionally designed (high P component in the error signal amplifier). This can only be done when accompanied by a large enough output capacity, if the aim is for no stability problems to occur.

[Advantages of the Present Invention] SUMMARY

[By applying the measures in] In accordance with the [features of Claim 1] present invention, it is possible to dimensionally design the control loop to have a low P component. The output capacities of the switching controller can be reduced without causing control stability problems. This leads to a smaller type of construction for switching controllers in high-voltage parts, where substantial outlay is required for smoothing capacitors.

[The] In accordance with the present invention [is based on the realization that, through a so-called forward (uni-directional) control], the control loop can be dimensionally designed to have a low P-component [; i.e., essentially] using so-called forward (unidirectional) control; circumventing the error signal amplifier[, the]. The step change in load is directly detected and delivered to the pulse-duration or pulse-frequency modulator, without the actual control loop having to respond. As a result of this precontrol, fewer automatic control delays follow step changes in load, without giving rise to stability problems.

When only the alternating component of the load current is detected for the precontrol, the precontrol decays with a time constant that can be selected such that the error signal amplifier can easily compensate for the decaying precontrol.

[Drawings] BRIEF DESCRIPTION OF THE DRAWINGS

[Exemplifying embodiments of the present invention are

elucidated detailed with reference to the drawing, whose figures show:

Figure 1:] Figure 1 shows a basic circuit diagram of a switching controller in accordance with the present invention[;].
Figure 2 [:] shows an evaluator for detecting a step change in load[;].
Figure 3 [:] shows the detection of the collector current of a traveling-wave amplifier.

[Description of Exemplary Embodiments] DETAILED DESCRIPTION

The switching controller illustrated in Figure 1 is designed as a [buck (step-down)] step-down controller. It has an input d.c. voltage source Q_E, including a terminal voltage U_E. Disposed between the positive pole of the input d.c. voltage source Q_E and the positive pole of the switching controller output having output voltage U_A is the series circuit of the switching controller's final controlling element S1 in the form of a switching transistor and inductor L of the switching controller. The freewheeling diode of the switching controller is denoted by DF, and the output-side smoothing capacitor by CG. Output voltage U_A is fed to an error signal amplifier KO, which compares it to a reference voltage Ur1. If output voltage U_A exceeds reference d.c. voltage Ur1, a control signal is transmitted to pulse-duration modulator PBM (non-inverting input), whose output signal determines the pulse duty factor (ON duration relative to OFF duration) of final controlling element S1. Connected to the inverting input of pulsewidth modulator PBM and of the common ground, is the series circuit composed of a resistor R1 and two signal sources Q_{SV}, Q_{SK}, which supply saw-tooth signals U_{SV} and U_{SK}. A voltage that is proportional to the input current of the switching controller drops across resistor R1. This is achieved in that resistor R1 is traversed by the flow of the rectified secondary current of

a current transformer SMW, whose primary winding is located at the input circuit of the switching controller between input d.c. voltage source Q_E and final controlling element S1. The signal source Q_{SK} carries a saw-tooth voltage:

$$U_{SK(t)} = \hat{U}_{SK}\ t/T$$

t indicating the time, T the period duration of the saw-tooth repetition frequency, and $\hat{U}_{SK}$ the maximum amplitude of the saw-tooth voltage. The maximum amplitude $\hat{U}_{SK}$ of the saw-tooth voltage is kept constant. RM designates the resistance value of resistor R1 for detecting the current through the final controlling element; [i.e.] i.e., in the case of current detection by a current transformer as in Figure 1, the resistance value multiplied by the reciprocal [[inverse]] (inverse) value of the transformation ratio of current transformer SMW. Then, $RM = \frac{R1}{ü1}$ applies, ü designating the transformation ratio of current transformer SMW. Thus, to be able to maintain the stability conditions, a certain minimum saw-tooth amplitude is required, which cannot be provided solely by the control as a function of output voltage U_A. One can modify the action of the current control amplitude by modulating the saw-tooth amplitude by way of the input voltage. For this, an additional signal source Q_{SV} is provided, which carries a saw-tooth voltage

$$U_{sv(t)} = \frac{1}{RC} \int_0^1 U_{E(t)}dt$$

Thus, this saw-tooth voltage $U_{SV}(t)$ is proportional to integrated input voltage $U_E(t)$. The time dependency of input voltage U_E of the switching controller is substantially the result of superimposed alternating components, such as a 100 Hz ripple voltage in the case of a switched-mode power supply. This noise is optimally suppressed when the arithmetic mean of current I_O through inductor L is

constant. To optimally suppress fluctuations in input voltage and satisfy the stability requirement, the conditions discussed in detail in European Patent No. 0 355 333 [B1 must be] are met.

[At this point, the] The present invention provides for the load step performance of the switching controller to be detected, in particular, the alternating component of load current I_L, to be suitably amplified, and fed via a coupling device E between error signal amplifier KO, [essentially] exhibiting P action, to pulse-duration modulator PBM, via an evaluation circuit A, which, in the present exemplifying embodiment, is arranged between output-side smoothing capacitor CG and an output terminal of the switching controller. The supplying of the load-step-dependent signal directly to the input of pulsewidth modulator PBM does not alter the stability of the controller, particularly with respect to phase margin and gain margin. As shown in Figure 1, coupling device E can be composed of a simple adding node or of an adding circuit, where the output signal from error signal amplifier KO is gated with the signal detected by evaluation circuit A. The two gated signals [are preferably] may then be fed to the adding node via resistors RF1 and RF2 of equal value.

As Figure 2 shows, the alternating component of load current I_L is expediently detected by evaluation circuit A via a measuring current transformer SW and an amplifier V that is connected in series therewith. If there is no change in the load current, [i.e.] i.e, no change in current I_L (e.g., given a step change in load), then there is no signal at resistor RF1. As is evident from Figure 1, given resistors RF1 and RF2 of equal value, the output signal from error signal amplifier KO is effectuated at pulse duration modulator PBM with the half-amplitude ½ U_{KO}. If the controller gain is now increased by a factor of two, it can be seen that the additional precontrol does not influence

the normal control loop via the signal that is detected by the evaluation circuit A; [i.e.] i.e, the controller stability is not changed. If the load then changes, namely if there is a modulation of the load current, then pulse duration modulator PBM is appropriately precontrolled without the actual control loop having to respond.

Since [preferably], for example only the alternating component of load current I_L is detected, the precontrol decays with time constant TAU = LH/RS, LH representing the primary inductance of measuring current transformer SW, and RS representing the cross resistance shown in Figure 2. Specifically, a great enough time constant TAU is selected to allow error signal amplifier KO to easily compensate for the decaying controller deviation of the precontrol.

Instead of a pulse duration modulator, a pulse frequency modulator can also be provided for the switching controller. Furthermore, the present invention can be used for any type of switching controller, such as an step-up controller, a flow transducer, an isolating transformer, etc. The present invention is particularly suitable for high-voltage parts for traveling-wave amplifiers in ground stations or satellites, where the smoothing or filtering outlay must be minimized. In these cases, the detected load current is, in particular, the collector current of the traveling-wave tube, which is transformed into the low-voltage side of the switching controller using measuring current transformer SW.

Depending on the type of switching controller and the disturbing influences, e.g. input voltage fluctuations, etc., the signals at the second input of the pulsewidth/frequency modulator that are needed for optimal controller stability are different.

In the switching controller represented in Figure 3 of European Patent No. 0 355 333 [B1], these are:

-- a saw-tooth signal Q_{SK} of constant amplitude;
-- a signal RMI_L that is proportional to the current that is conducted through final controlling element S1; and
-- a saw-tooth signal Q_{SV}, whose peak amplitude is selected in proportion to the integrated input voltage of the switching controller.

In the [exemplifying] example embodiment [represented] shown in Figure 2 of EP 0 355 333 [B1], a d.c. voltage signal U_W is also included, which is selected in proportion to the level of the input voltage of the switching controller.

According to the present invention, it is possible to obtain a signal that is dependent upon the step change in load using a quantity other than the load current, for instance by detecting voltage jumps in the power circuit of the switching controller. These quantities can be suitably processed and fed as precontrol signals to the pulse-duration modulator or frequency modulator.

In the [exemplifying] example embodiment represented in Figure 3 of the present invention, the alternating component of the collector current of a traveling-wave amplifier is detected. The switching controller is used here as precontroller for a push-pull transformer GW. A high-voltage transformer HT that delivers the supply voltages for traveling-wave tube WF via high-voltage rectifier circuit HG is located in the output circuit of push-pull transformer GW. The primary winding of measuring current transformer SW1 of evaluation circuit A for evaluating collector current IC is located in the collector feed line to collector K of traveling-wave tube WF. The secondary coil is connected as [represented] shown in Figure 2. The output of evaluation circuit A leads via resistor RF1 to coupling device E, as [represented] shown in Figure 1. In traveling-wave tubes having two collectors, it usually suffices to evaluate one collector current as [represented] shown in Figure 3,

particularly the current of the collector that is situated in the immediate vicinity of the Wehnelt cylinder.

Abstract of the Disclosure

In a switching controller whose error signal amplifier [(KO)] essentially exhibits P action, the load step performance of the switching controller is detected via an evaluation circuit[(A)]. This signal is fed directly to the pulse- duration or pulse-frequency modulator [(PBM)] for the final controlling element[(S1)], substantially circumventing the error signal amplifier [(KO)] for the switching controller. [ ]Through this measure, output capacities of the switching controller can be reduced without stability problems.[

Figure 1]